NOTES ON THE SIGNIFICANCE OF THE BIOTA AND OF BIOGEOGRAPHY[1]

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Introduction; Requirements of Species; The Biota, A Response to Geographic Conditions; Influences of the Biota; Biogeography and Human Geography.

I. Introduction

Although the native flora and fauna represent but a small portion of the life which in any area ultimately may be put to the use of civilized man, and many include a few species of conspicuous economic significance, their study is well worth while for several reasons. (1) It makes practicable a comparison even of widely separated areas in respect to climate, ground-water and soil. (2) It greatly extends our knowledge of geographic conditions, making possible, for example, an intelligent selection of useful varieties of plants and animals which may be introduced with probable success. (3) The flora in many cases is an indication of the agricultural possibilities of an area. (4) Vegetation and animals affect run-off, erosion, and soil. (5) The native biota has vastly influenced human activities, and its study therefore is a prerequisite to a full understanding of the human geography of any region. These points will be taken up after a brief discussion of some requirements of species and some differences between the original and possible future biotas.

II. Requirements of Species

Each species has many and in most cases complex requirements, such as proper amounts of (1) moisture, including water vapor as well as liquid water; (2) heat, including requisite periods when the temperatures are above definite minima—for example, 32°; (3) light, including sunshine; (4) food, inorganic as well as organic; (5) appropriate anchorage for sessile forms; (6) proper sites in which to rear their young; (7) not too powerful rivals or enemies; (8) effective means of dissemination. Moreover, various plants are fertilized by but few, and some of them by highly specialized insects.

[1] Professors R. D. Salisbury, J. Paul Goode, Henry C. Cowles, and Victor E. Shelford made valuable suggestions during the preparation of this paper, for which assistance acknowledgment is hereby gratefully made.

The range of such plants cannot extend much beyond that of such insects unless they are propagated vegetatively.

An environment may be favorable in almost all respects to various species which are not found there, but if only one of the numerous requirements is unfulfilled that species is barred. In a region where the climate is highly variable, an area perhaps may be favorable for a given species during most years, but the exceptional drought or the occasional unseasonable frost may keep the species out. Species which possess means of prompt reintroduction may be re-established soon after local extermination. The great significance of means of dispersal is indicated by the fact that the terrestrial species which are most widely distributed are those which are distributed through the air by the winds, as willows, birches, poplars, bacteria, diatoms and fungi, or those that are able to fly, as most insects, birds, and bats; while the next most widespread are those disseminated through the agency of civilized man. Deficiency in means of dispersal tends to retard greatly the spread and to restrict the ranges of many interdependent groups, as examples of which are tree-squirrels and nut-bearing trees, fruit-eating birds and bats and certain trees and shrubs. Herbs whose seeds are armed with hooks depend largely upon wide-ranging mammals for their spread. Numerous animals are carried by others while in egg, larval, or adult stages. Examples are certain molluscs which attach themselves to the gills of fish, and all parasites, many of which cause sickness and produce "diseases."

There are numerous illustrations of the success of species which have crossed the barrier of sea, mountain or other unfavorable tract and have become established in other areas: the English sparrow, Norwegian rat, house mouse, and, in Australia, the rabbit, among the vertebrates; the house fly, tent caterpillar, bedbug, potato beetle, and many other insect pests; the Russian thistle, sweet-clover, and pigweed in America among the plants, and many others elsewhere, for instance, the braken fern and aguave in Australasia, and the cactus in the Mediterranean region.

Many additional species may prosper if conditions are improved but slightly in one or more particulars. Thus slight improvement in (1) planting, (2) cultivation, (3) supplying water at critical times and places, might enable some species not now represented to establish themselves. Wells have increased in many respects the utility of areas naturally deficient in drinking water. The marvelous results of irrigation are well known. (4) The virtual lengthening of the season by affording protection in the early stages of

growth by means of hotbeds for various vegetables. (5) Protection from enemies. The animals of prey have been nearly exterminated over large areas. (6) The elimination of competitors. The bison, antelope, and mustangs were rivals of cattle, sheep and horses, and were of necessity nearly exterminated before the latter became common. Without the breaking up of the sod and the consequent destruction of the native vegetation of the area affected, the raising of nearly all crops would be impossible in many regions.

For these reasons and perhaps others the flora and fauna which will occupy most areas when they finally are put to maximum use by highly civilized man will be far more abundant, profitable, and diverse than those which originally prevailed, and probably richer in species, although many native species will be exterminated over large areas. This enrichment will take place along at least the following lines: (1) Similar regions the world over will yield species which will be introduced and put to the use of man. (2) Some of the plants, now useless, doubtless will become useful with the advance of civilization. Two decades ago, for example, it was not anticipated that the guayule shrub would give to desert lands where it grows a value of as much as $20 per acre, which it now does because it became profitable to extract the rubber which it was found to contain. (3) The improvement of native stocks by hybridization and selection has accomplished much and has great possibilities. (4) The acclimatization of certain forms not at first successfully raised is practicable[2]. (5) A thorough adjustment of the biota to the geographic conditions, especially climate and soil, would enormously increase the productivity of the area. (6) Improved methods of transportation and preservation and increased local markets may make it profitable to put all portions of the area to more effective use. (7) Drainage or irrigation of areas susceptible thereto very greatly increases their productivity. (8) The addition of various substances to the soil often enables it to support a richer biota.

Because large areas were primitively, or still are very uninviting does not prove that they will not support a large population in the future. Most irrigated areas were exceedingly unattractive until they were irrigated, when they became worth more than $100 per acre in most regions. Areas, miles in extent, which in the range days could not permanently support a single steer because of the occasional lack of drinking water and winter food can now, with

[2] For an excellent discussion of these four methods see Hedrick, U. P.: "Multiplicity of Crops as a Means of Increasing the Future Food Supply," *Science*, Oct. 30, 1914, pp. 611–620.

the help of wells, a small amount of hay, and shelter, support scores per square mile. Great confidence is expressed by those best entitled to an opinion that within a decade or two much of the sod of millions of acres of the semi-arid regions will be sprinkled with luxuriant plants of certain Siberian and hybrid strains of alfalfa, and thus the productivity of certain lands increased from nearly nil to exceed that of the present best grazing lands of the region.

Although the original biota thus differs widely from the biota likely to prevail under conditions of high civilization and dense population, its study is distinctly valuable as a preliminary step in the determination of the geographic conditions of the area.

III. The Biota as a Response to Geographic Conditions Extends Our Knowledge of These Conditions.

Biogeography extends our knowledge of geographic conditions in various ways. Some of them are listed below:

1. Climatic data of nearly all sorts may be greatly supplemented.
2. The general geographic conditions are indicated by the ecological aspects.
3. Slight variations in these general conditions are marked by corresponding changes in vegetation and animals.
4. Many differences in the various climatic factors are revealed.
5. Differences in soils are indicated in many places.
6. The nature of the subsoil and the depth of the soil is revealed at many points.
7. The depth to the water-table is shown in many places.
8. Many slight differences of slope or elevation are made conspicuous.
9. The likelihood that an area will be flooded, or, in case of areas normally submerged, will be exposed, is shown in many places.
10. The value of certain areas for the production of certain crops is suggested.
11. The rate of erosion of slopes is suggested.
12. The directions or points of the compass are indicated roughly by various plants and animals.
13. The physiographic or even geologic history may be illuminated.

These points demand some further discussion:

1. Climatic data of nearly all sorts are greatly supplemented: In mid-latitudes, especially in continental interiors, there may be great climatic variation from year to year and decade to decade. Records of a moderately satisfactory sort cover but a short period for many areas. Therefore in many districts the local climatic records permit only an imperfect knowledge of the climate. By using the dominant species as an index, comparison may be made with corresponding areas which have records that cover a much greater interval.

The dominant native plants and animals of any region have been selected not by the climate of a brief period, a decade or even a century, but by that of centuries. The study of the native biota therefore makes possible in many places a very great extension of knowledge concerning the climate.

2. The general geographic conditions are indicated in most places by the ecological aspects of the biota, and therefore supply indices for comparison of areas: Plants closely similar in appearance (ecological aspect) have evolved in various plant families under the influence of similar conditions. Certain spurges in the drier parts of South Africa very closely resemble American cacti. Arborescent representatives of most families are found in the tropical rain forests; even the grasses and horsetails are represented there by forms which might be classed as arborescent. The plants of grasslands are chiefly herbaceous. Plants resembling the sage are found in all steppes, and the pin-cushion, pillow and carpet types of growth are developed at high elevations or in high latitudes by members of nearly all plant families which are represented there.

If two environments—for example, southern Siberia and western South Dakota—present the same ecological aspects and types, and perhaps many representatives of identical genera and species, the chances are that a species from one environment will thrive in the other, if introduced. Various strains of Siberian alfalfa have been introduced into South Dakota, and some give great promise. The introduction of forms from regions quite unrelated, ecologically, is, on the other hand, much less likely to be successful. The resulting loss may be much greater than the direct loss because of the discouragement to the introduction of new varieties which one failure usually produces.

3 and 4. Minor climatic differences are shown in many places by minor differences in the biota:

The effects of decreased evaporation or increased precipitation are shown by differences in the ecology of different areas occupied by a general ecological type, as between the southern and northern parts of a prairie, steppe or woodland. Plants such as the twinflower (*Linnea*) or bunch-berry (*Cornus*), which are restricted to the moister or more mesophytic sides of valleys at low elevations in the southern or warmer part of their range, are much more widespread in the northern part, and at higher elevations.

The persistence and velocity of the wind at various exposed

points is shown by the stunted (krumholtz) character of the woody growth, and the direction from which the prevailing winds blow is shown in many cases by the lopsided shape of trees.

As an illustration of the indication of minor temperature differences the following case showing a conspicuous influence of a season somewhat longer than the average and free from killing frosts may be cited. In Harding County, in the northwestern corner of South Dakota, wild plum thickets are numerous and extensive on portions of the slopes of the forested buttes, while they are rare elsewhere in that part of the state. The local Weather Bureau stations, which are all in the valleys, record a frostless season usually too short for even wild plums. Their abundance on the sides of the buttes indicates clearly a longer frostless season at that elevation. An observing horticulturist has located in this belt an apple orchard which has yielded well for several years. Similar belts are indicated by the native vegetation in many other areas.

5. Differences in soils are indicated by the material brought up by burrowing animals and in many places by different types of vegetation.

Some species of plants grow on a great variety of soils; many others thrive best on certain types, while still others are highly characteristic of a single type. Soil conditions therefore may be recognized commonly by the predominance of different species of plants, and often may be differentiated when seen even from a distance by the shades of color that dominant species give to such areas. A better illustration of this can scarcely be found than at the northeastern corner of the Black Hills, where, from Bear Butte, more than a dozen types of soils, weathered from numerous rock formations which outcrop thereabouts, are distinguishable by the aid of their vegetal covering. On the heavy clay, chenopods and wheat grass give a dark green or brown color. The sandy soil is clothed with tall, stiff, usually straw-colored sand grass, or the reddish-yellow bunch grass. Sandy-loam areas have the shorter, light-colored cover of needle grass which waves conspicuously in the breeze. The clay-loam and silt have a velvet-like buffalo-grama grass carpet. Gravelly areas are blotched with the low shrubs of the lead plant where the matrix is loam; where it is silt, the color is lightened with some species of sage, a genus dominant on many areas of silty soil. In the foothills where sandstones outcrop there are scattered pines; where shale outcrops in that locality, there are no trees. The contact between the limestone and the redbeds

is made conspicuous at a distance of many miles, because pines occupy the limestone to its very margin in most places.

6. The nature of the subsoil and the depth of the mantle rock are revealed at many points.

Materials brought up by burrowing animals are perhaps commonly sufficient indications of the nature of the subsoil.

The thickness of the soil and of the mantle rock is shown clearly in the distribution or character of various species of plants and burrowing animals in areas where firm rock is near the surface.

7. The depth to the water table is shown in places where the depth is not great. The establishment, at such points, of the general water-level makes possible an approximation of the depth to permanent water in wide areas where the depth is too great to be reached by most local vegetation.

The accessibility of underground water is shown strikingly by the distribution of certain kinds of trees. The fringe of cottonwood along the watercourses, the groves of willow, ash, elm, and several other kinds occupying portions of the river bottoms, the little thickets or single trees near hillside springs, all indicate clearly available ground-water.

Various sedges and rushes grow only in areas where seepage takes place, at least part of the time. Lignite, which is relatively impervious, causes seepage in many places where it outcrops on slopes. Vegetation in such zones is fairly conspicuous, and has been used often in locating "coal diggings."

It appears that prairie-dog towns are located only where the water table is within reach of these able burrowers. The location of more than 100 towns examined in Harding, Perkins, Fall River, Stanley, and other South Dakota counties seems to bear out this statement[3].

8. Slight differences of slope or elevation are made conspicuous by differences in the vegetal covering in many places.

In swampy areas very slight differences in elevation commonly are accentuated by distinct differences in vegetation, and in many places the depth of water in lakes and marshes is suggested clearly in the distribution of reeds, sedges, water-buttercups, pond-lilies and other plants. On slight slopes the depressions and the direc-

[3] The one small town which might at first seem to contradict this generalization is on the table near the north end of the West Short Pine Hills in Harding County. As permanent springs are numerous at the base of the Miocene formation where it outcrops on the margins of this table, some 30–50 feet below the level of the town, it is probable that water may be obtained at a corresponding level beneath the dog town. The selecting of the site for this town might lend support to those who advocate that animals possess the power to reason.

tion of slope are in many places conspicuously indicated by differences in the vegetation.

9. The likelihood that an area will be flooded is shown in many places.

Certain species, notably of grasses and terrestrial animals, are unable to resist even occasional floods, and are lacking in areas where floods occur, while certain plants, such as cottonwood and some willows, become established at the margin of flooded areas and, dead or alive, may long indicate the flood. The biota of areas, normally submerged but occasionally exposed, differs somewhat strikingly in many places from that inhabiting areas permanently submerged. Bodies of water which never freeze to the bottom are inhabited by a richer biota than are those that freeze occasionally.

10. The value of certain areas for crops is suggested in many places.

The significance in this respect of the types of forest is well known, but other plant associations are indicative of value; in grassy plains "land which bears a pure short-grass cover was found to be supplied with water in the surface foot or two of soil only, and usually even to that depth for but a brief period during spring and early summer. Land with a uniform cover of tall grasses was found to be supplied with water to a much greater depth and to offer conditions favorable for plant growth during a much longer season. As a connecting link between these two conditions a short grass cover which supports a scattered growth of taller plants was found to indicate intermediate conditions as regards water supply.

"The areas of greatest agricultural value, one year with another, are those marked by the presence of the wire-grass vegetation. Of almost equal value are the areas characterized by those phases of the grama-buffalo-grass vegetation which are distinguished by the presence of a considerable quantity of Psoralea or of wire-grass. Bunch grass land is best for crops during especially dry years, but is relatively the least productive during favorable years. Typical short-grass land (grama-buffalo-grass association) produces more than any other type during wet years, but is first to fail in time of drought."[4]

11. The rate of erosion of slopes or of deposition is suggested.

In most places bare slopes indicate rather rapid erosion, and slopes covered with vegetation, notably trees, indicate much less rapid erosion. In the sandhills, dunes which have remained rela-

[4] Shantz, H L.: *Bureau of Plant Industry Bulletin No. 201*, 1911, Summary.

tively stationary for a lengthy interval have considerable vegetation, in some cases trees at least on their north-facing slopes.

12. The directions are roughly indicated by certain plants and animals.

The leaves of the compass plant (*Silphium*) usually have their edges in a north-south direction; several kinds of lichens and mosses are found chiefly on the north side of trees and stones; the vegetation on a steep north-facing slope is somewhat markedly different, in most places, from that on a steep south-facing slope; several burrowing animals (ants, badger, prairie-dog), either in the distribution of the material brought up or in the direction of the burrow, give a rough approximation as to directions. Woodpeckers' holes generally are on the northeastern or eastern side of a limb or tree The entrance to covered nests of such birds as the meadow-lark, oven-bird and marsh-wren in most cases is on the east.

13. The physiographic, and even some points in the geologic history, may be illuminated by the distribution of species, especially their presence or absence in areas now favorable to them. Bluffs along most valleys become covered with vegetation soon after the stream ceases to erode at their bases. The age of trees on such slopes, as also of those in ravines and on terraces and alluvial fans, suggests the age of these physiographic features. The presence in the Black Hills of numerous boreal species such as the white spruce *(Picea alba)* and the marmot *(Marmota dacota)* suggests that during the geological past (the glacial period) such species were widespread in this latitude. With the change of climate some have been stranded in the Black Hills. The similarity, or even specific identity, of many Alpine plants of all lofty mountains of the northern hemisphere is probably to be accounted for in the same manner.

IV. Influences of the Biota

In addition to increasing geographic knowledge in the various ways mentioned above, the biota affects run-off, erosion, soil, and evaporation.

The percentage of the precipitation which runs off is affected by the biota. Burrows of worms, insects, amphibians and mammals, footprints of heavy animals, and roots, especially decayed ones, facilitate the entrance of water into the soil. Matted and coarse vegetation especially retards run-off.

Erosion is retarded by a vegetable covering. The disintegration of rock by temperature changes is also retarded by vegetation. The

decay of rock materials by chemical means is facilitated by the secretions and remains of plants and animals. Animals in general accelerate erosion, especially on steep slopes.

Soil is mixed and extended by burrowing animals, which also increase aëration and oxidation. All animals and plants contribute organic matter to the soil. The roots of plants are potent factors in rupturing rock. By retarding the washing away of soil, however formed, plants are powerful agents in the accumulation of a deep soil.

Water which otherwise would run off is conserved in soil clothed with vegetation, and given up gradually by evaporation, which process lowers the temperature and increases the relative and absolute humidity; therefore evaporation of soil moisture normally is increased by the vegetal covering.

V. Biogeography and Human Geography

Human activities in an area are determined largely by the geographic conditions which prevail there. The biogeography reflects but slightly geographic location, area and the mineral resources, though climate, soil, topography, and water conditions influence and are influenced by the biota.

The native biota is a geographic factor of great human significance. The following illustrations applicable to South Dakota indicate a few of its manifold influences:

1. A grassy area facilitates grazing and agriculture, as woods have to be cleared, in most cases laboriously, before extensive tillage or pasturage is possible.

2. Where the sod is tough, laborious breaking necessarily precedes agriculture.

3. Travel across country is facilitated by firm sod.

4. Plains which are covered periodically by dry grass permit of widespread prairie-fires and necessitate foresight, care, and coöperation on the part of the settlers.

5. Where but little of the area is wooded the importation of wood is necessary and wood is valued highly. The small area of woodland in South Dakota is less of a handicap than it might otherwise have been because (a) lumber serves as "return freight" in cars which are used for the export of wheat, cattle and other bulky commodities. In portions of the state which do not export large quantities of such produce the cost of lumber is much

greater; (b) barbed-wire became fairly cheap before it was extensively needed for fencing; (c) ash groves, widely distributed along the valleys, and cedar thickets in portions of the western part of the state furnished a large share of the posts required. The character of the upland (nearly level and heavily sodded) made the hauling of posts and firewood less expensive than it might otherwise have been; (d) lumber mills were erected early in the Black Hills, the forested buttes in Harding County and along the lower Missouri River, and the local demand was supplied, at least for a time.

6. The type of the grassy covering has influenced greatly the grazing industry. In many portions of the earth, grazing is less profitable than in the northern Great Plains. This is due, in no small degree, to the "natural hay" which is formed under the influence of the scanty rainfall of autumn and winter. The growth of many kinds of grass ceases before there are heavy frosts, and the nutriment largely remains in the dried standing grass until the rains of the following summer.

7. Where game birds and mammals were abundant, they made possible the establishment of permanent agricultural settlements before they would have been successful without this assistance.

8. Where fur-bearing mammals are numerous, skins, a natural commodity which usually has high value, are available for export

The "fur trade" had become unimportant in the Great Plains before permanent agricultural settlement commenced, and therefore it influenced the settlement slightly. However, the trapping of fur-bearing animals has been carried on incidentally by many persons, and has contributed not a little to the firm establishment of many pioneers and some later settlers.

9. Where animals of prey, such as wolves, coyotes, bears, pumas, and horned owls are plentiful, as they formerly were or still are in many parts of the world, their numbers must be depleted before various sorts of live stock and poultry can become very profitable.

10. Where herbivorous animals of certain kinds, such as bison, prairie-dogs, rabbits, locusts, are very numerous, their reduction is an essential antecedent to success in various human activities. The same may be said of poisonous animals and plants.

11. Various animals, especially birds and insects, have been valuable allies of man in his struggle against undesirable animals and plants ("weeds"). Predatory insects, of which there are

many sorts, including various spiders, hymenoptera, and ground beetles, are powerful enemies of numerous plant-eating insects. Various insects, of which the milkweed bug and monarch caterpillar are examples, feed solely or chiefly upon certain weeds.

12. Wild fruits, berries, seeds, nuts, and roots contribute to the food supply of many persons, and in some instances were of great significance to pioneers and others.

OUTLINE FOR FIELD WORK IN GEOGRAPHY*

By WELLINGTON D. JONES and CARL O. SAUER

This outline has been prepared in recognition of the need of defining scope and methods of geographic field work. It is comprehensive enough to be adapted readily to almost any region. Although planned for individual, detailed field research, it also may be helpful in field work of other sorts. Numerous hints on preparations for field work and on field methods are given in order that the inexperienced field-worker may avoid some of the difficulties which commonly are encountered.

I. Preparations for Field Work

1. *Reading the literature on the area*
   a. Before going into the field, the greatest familiarity possible should be acquired with the available literature, including (1) physiographic studies and their geologic basis, and (2) articles on economic and social conditions.
   b. Notes should be made on important points. In notes distinguish between abstracts and quotations. Cite author, title, and page. In some cases such notes should be taken into the field.
   c. Study pictures from the area. Illustrated pamphlets issued by railroads and steamship lines are helpful in many cases.
2. *Acquisition of maps*
   a. Those available may include topographic, geologic, soil, hydrographic, vegetation, climatic, and land office.
   b. Maps not available for field use may be traced or photographed.
   c. Maps intended for much use in the field should be cut in sections and mounted on cloth (paper muslin).
3. *Outline of campaign*
   a. Information of value in shaping field plans may be secured by correspondence with (1) well-informed residents of the area, such as merchants, bankers, county officials, experienced teachers, (2) members of geological, forest, and soil surveys.

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* The outline embodies numerous corrections and additions suggested by the Seminar in Geography of the University of Chicago, before which it was presented in the Winter Quarter of 1915. In its preparation use was made of an unpublished outline by H. H. Barrows for a field class in the Cumberland Plateau and Southern Appalachians, of Hayes' Handbook for Field Geologists, and of a paper by D. W. Johnson on "Field Methods in Physiographic Geology," in Economic Geology, Vol. VIII, pp. 713-20. At the suggestion of the Editor, the outline was submitted to Wallace W. Atwood, Isaiah Bowman, W. H. Hobbs, Mark Jefferson, and Bailey Willis. Their comments and criticism have been used freely and hereby are gratefully acknowledged.

Reprints may be secured at cost by addressing Dr. W. D. Jones, Rosenwald Hall, University of Chicago, Chicago, Ill.